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Specification

1. Title of Invention

Acoustic lens composition

2. Claims

Acoustic lens composition featured in that it consists of
1) diorganopolysiloxane, or silicone rubber compound of which diorganopolysiloxane is the principal constituent 100 parts by weight,
2) alumina or titanium oxide powder of the average particle size 0.1 ~ 1.0 μm 50 ~ 150 parts by weight,
and
3) thermoplastic resin powder of the average particle size 0.1 ~ 50 μm and the melting point 80°C or higher 10 ~ 100 parts by weight.

3. Detailed Description of the Invention

(Area of application in industry)

The present invention relates to acoustic lens composition, and specifically, it relates to the acoustic lens composition which is useful as the acoustic lens material of the probe of the ultrasonic diagnosis equipment to form an acoustic lens of which the acoustic impedance can be brought close to that of the living body while the acoustic velocity is maintained at 900 ~ 1,100 m/sec, and at the same time, the ultrasonic attenuation in the high frequency region is small and thus the resolution is high.

(Conventional technology)

Since the essential conditions for the acoustic lens of the probe of the ultrasonic diagnosis equipment are that it can focus the ultrasonic wave and also it can adhere well to the living body so that the reflection of the ultrasonic wave at the interface with the living body can be minimized, that the ultrasonic attenuation of the lens itself is small, and also that its mechanical strength is high and it is chemically stable, silicone rubber that inorganic

fillers such as silica, alumina, titanium oxide, etc. are added to organopolysiloxane has been used.

Previously, to the silicone rubber used in this kind of application a large amount of filler has been added in order to increase the density so that its acoustic impedance would match with that of the living body. However, when the filler of high density is used in order to increase the density, it generates negative effects such as the decrease of acoustic velocity, and in this case, for example, when the acoustic impedance is brought close to that of the living body, the ultrasonic attenuation of the acoustic lens increases by the addition of filler in a large amount, and this causes such a disadvantage that its sensitivity is lowered in the high frequency region of 5 MHz or higher, and also it has been known that this attenuation is proportional to the particle size, the mixing ratio, and the density of the filler rather than the kind of filler.

(Constitution of the invention)

The present invention relates to the acoustic lens composition which solves such a disadvantage, and is featured in that it consists of 1) diorganopolysiloxane, or silicone rubber compound of which diorganopolysiloxane is the principal constituent, 100 parts by weight, 2) alumina or titanium oxide powder of the average particle size 0.1 ~ 1.0 μm, 50 ~ 150 parts by weight, and 3) thermoplastic resin powder of the average particle size 0.1 ~ 50 μm and the melting point 80°C or higher, 10 ~ 100 parts by weight.

Namely, the present inventors carried out various studies on the acoustic lens of the probe of the ultrasonic diagnosis equipment in order to obtain one of which the ultrasonic attenuation is low even when its acoustic impedance (acoustic velocity × density) is held close to the acoustic impedance of the living body, $1.4 \sim 1.6 \times 10^6$ Kg/m^2·sec, and also the acoustic velocity at 900 ~ 1,100 m/sec. As a result, they found that, although it is useful to add such high density filler as alumina, titanium oxide, etc. to increase the overall density as the method to bring the acoustic impedance of silicone rubber close to the target value, the acoustic velocity is lowered, if this is the only measure being taken, and since a large amount of addition is required to bring the acoustic impedance close to the target value, the attenuation is increased, and its practicality is lost particularly in the high frequency region of 5 MHz or higher. However, it was found that, if thermoplastic powder such as nylon powder is added to this, the acoustic velocity can be increased, and the ultrasonic attenuation of the composition can be reduced. Then, after further studies on the silicone rubber used here, the kind of the thermoplastic resin powder, the particle size, the amount of filling, etc., the present invention has been completed.

Diorganopolysiloxane as the first component to constitute the composition of the present invention is shown by the formula $R_2SiO_{(4-n)/2}$, where R is selected from alkyl groups such as methyl group, ethyl group, propyl group, butyl group, etc., alkenyl groups such as vinyl group, allyl group, etc., aryl groups such as phenyl group, tolyl group, etc., cycloalkyl groups such as cyclohexyl group, etc., or the aforesaid groups in which a part or the whole of hydrogen atoms bonded to carbon atoms are replaced with halogen atoms, cyano groups, etc. such as chloromethyl group, trifluoropropyl group, cyanomethyl group, etc.. Preferably it is an identical or different, unsubstituted or substituted monovalent hydrocarbon group, of which at least 50 % is methyl group. n is 1.98 ~ 2.02. The molecular chain of this thing is capped with trimethylsilyl group, dimethylvinylsilyl group,

hydroxyl group, etc., and it is usually preferred to be gummy substance with the viscosity several millions centistokes, but it can be liquid of about 500 to 100,000 cS.

However, this diorganopolysiloxane can also be in the form of silicone rubber compound that the fumed silica as the reinforcing filler is added to the diorganopolysiloxane as the base polymer by the preset amount, for example, 5 ~ 40 parts by weight to the base polymer 100 parts by weight.

Now, the inorganic filler as the second component of this composition is required to increase the density of this composition, and thus alumina of the density (d) 3.9 or titanium oxide of the density 4.2 is selected. It is necessary to set its average particle size in the range of 0.1 ~ 1.0 μm because, if the average particle size is less than 0.1 μm, it is difficult to fill it in high density, and the ultrasonic attenuation cannot be reduced, and if it exceeds 1.0 μm, the attenuation increases and its practicality is lost. Also, the amount of this addition is necessary to set in the range of 50 ~ 150 parts by weight to the aforesaid first component 100 parts by weight because, if it is less than 50 parts by weight, it is too little to expect density increase of this composition, and if it exceeds 150 parts by weight, the attenuation increases and also the acoustic velocity is lowered, and the more preferable range is 60 ~ 120 parts by weight.

Also, the thermoplastic resin powder as the third component to constitute this composition can be the one on the market, and its average particle size is required to be in the range of 0.1 ~ 50 μm because, if the average particle size is less than 0.1 μm, it is difficult to fill it in high density and also it is difficult to procure it, and if it exceeds 50 μm, the attenuation increases and also the mechanical rubber characteristics after vulcanization are degraded. Considering that the one with the acoustic velocity 2,000 m/sec level is suitable for the improvement of the acoustic velocity, nylon, poly(vinylidene fluoride), polyethylene, polymethylmethacrylate, polystyrene, etc. are preferable choice. Also, it is necessary to set the amount of this addition in the range of 10 ~ 100 parts by weight to the aforesaid first component 100 parts by weight because, if it is less than 10 parts by weight, the improvement of the acoustic velocity cannot be expected, and if it exceeds 100 parts by weight, the acoustic velocity increases too high even if the amount is balanced with the addition of the second component, and in addition, the attenuation increases with this high filling. Incidentally, if the melting point of this thing is too low, the shape of the powder is deformed during mixing with the aforesaid first component and second component, causing aggregation and coarsening of the particles, and therefore, the melting point is required to be 80°C or higher.

The composition of the present invention can be obtained by uniformly mixing and kneading the preset amounts of the aforesaid first through third components, and diorganopolysiloxane or silicone rubber compound as the first component of this thing is, as needed, vulcanized to be used as the elastic body, and for this vulcanization, known organic peroxide such as benzoyl peroxide, 2,4-dichlorobenzoyl peroxide, dicumyl peroxide, 2,5-dimethyl-2,5-di(t-butylperoxy)hexane, etc. is added, followed by heating to a preset temperature. In case this diorganopolysiloxane as the first component is containing unsaturated group such as vinyl group, its curing may be carried out by the addition reaction by adding organohydrogenpolysiloxane, which contains a silicon atom-bonded hydrogen atom which can make addition reaction with this vinyl group, and platinum catalyst.

In order to form an acoustic lens for the probe of the ultrasonic diagnosis equipment from the composition of the present invention, this composition is molded by an appropriate means such as press molding, and vulcanized, and the acoustic lens obtained in this manner shows, due to the addition of the second and third components, the acoustic velocity 900 ~ 1,100 m/sec and also the acoustic impedance close to that of the living body, and the ultrasonic attenuation in the high frequency region of 5 MHz or higher is also reduced, and therefore, its resolution is high.

In the following, examples of the present invention are described, and in the examples, parts shows parts by weight and the viscosity is the value measured at 25°C.

Example 1, comparison examples 1 ~ 2

Alumina of the average particle size 0.4 μm, ASE-12 (trade name for the product of Sumitomo Aluminum Metallurgy), 80 parts, and nylon powder of the average particle size 4 μm, SP-500 (trade name for the product of Toray), 35 parts were added to dimethylvinyl-capped dimethylpolysiloxane with the viscosity 5×10^6 cS and the vinyl group content 0.02 mole % 100 parts, and kneaded with a two roll mill, and subsequently by using a high speed three roll mill they were dispersed uniformly.

Subsequently, 2,5-dimethyl-2,5-di(t-butylperoxy)hexane 0.5 part as the vulcanizing agent was mixed to this composition 100 parts, and the mixture was press-molded at 165°C for 10 minutes to fabricate 2 mm thick sheet (hereafter abbreviated to sheet 1). For the sake of comparison, by replacing alumina in the foregoing by alumina of the average particle size 5 μm, AL-24 (trade name for the product of Showa Light Metals), 80 parts and then by processing similarly, 2 mm thick sheet (hereafter abbreviated to sheet 2) was fabricated, and also, by replacing nylon powder in the foregoing by poly(vinylidene fluoride) of the average particle size 100 μm, KF+1,000 (trade name for the product of Kureha Chemical), 35 parts and then by processing similarly, 2 mm thick sheet (hereafter abbreviated to sheet 3) was fabricated. Acoustic characteristics of these samples were studied and the results are shown in Table 1.

Table 1

Items		Example number	Example	Comparison example	
			1	1	2
		Sheet number	1	2	3
Amount of addition	Alumina (average particle size)		ASE -12 (0.4 μm)	AL-24 (5 μm)	ASE-12 (0.4 μm)
	Thermoplastic resin (average particle size)		Nylon SP-500 (4.0 μm)	Nylon SP-500 (4.0 μm)	Poly(vinylidene fluoride) KF+1,000 (100 μm)
Physical properties	Density (g/cm^3)		1.38	1.38	1.50
	Acoustic velocity (m/sec)		1043	1051	1020
	Acoustic impedance ($\times 10^6$ $Kg/m^2 \cdot sec$)		1.44	1.45	1.53
	Attenuation	Ultrasonic frequency			
		3.5 MHz	19	62	70
		5.0 MHz	28	90	105
		7.5 MHz	51	112	120

Example 2

Titanium oxide of the average particle size 0.3 μm, CR-93 (trade name for the product of Ishihara Sangyo), 70 parts and nylon powder of the average particle size 7.5 μm, Dye-amid* WS (trade name for the product of Fuji Chemical), 30 parts were added to 100 parts of silicone rubber compound which was prepared by adding fumed silica of the specific surface area 200 m^2/g, Aerosil* 200 (trade name for the product of Nippon Aerosil), 20 parts to dimethylvinyl-capped dimethylpolysiloxane raw rubber which was containing phenyl group 10 mole % and vinyl group 0.15 mole % and of the viscosity 3×10^6 cS, 100 parts, and mixed and kneaded with a roll. This composition was processed similarly to the example 1, and vulcanized sheet was fabricated. The acoustic characteristics of this thing were the density 1.37, the acoustic velocity 1,038 m/sec, and the acoustic impedance 1.42×10^6 $Kg/m^2 \cdot sec$, which were satisfactory enough for the acoustic lens.

* Transliteration for the trade name. TTTS